N64-22094 Code None-cat 14

8p.

JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR VOLUME 6, NUMBER 4 OCTOBER, 1963

DEVELOPMENT OF A COMPLEX MULTIPLE SCHEDULE IN THE CHIMPANZEE

RICHARD E. BELLEVILLE,[1] FREDERICK H. ROHLES, MARVIN E. GRUNZKE, AND FOGLE C. CLARK

22094

AEROMEDICAL RESEARCH LABORATORY
HOLLOMAN AIR FORCE BASE, NEW MEXICO[2]

The development of chimpanzee behavior on a four-component, three-lever multiple schedule is described. Component schedules included the Sidman avoidance procedure with a concurrent discriminated avoidance schedule on a second lever, fixed ratio performance for food, differential reinforcement of low rate for water requiring a dual response chain, and a symbol discrimination task for continuous food reinforcement using three levers. The avoidance component of this schedule was employed during the January 31, 1961 suborbital space flight of the chimpanzee "Ham." On November 29, 1961, the chimpanzee "Enos" performed on the multiple schedule during three orbits around the earth in a Mercury capsule.

AUTHOR

In a multiple schedule, rewards are programmed by two or more schedules presented one at a time, often in a repeating series with each schedule accompanied by a discriminative stimulus (Ferster and Skinner, 1957). The advantages, as well as possible disadvantages, of employing this type of schedule have been discussed by other investigators (Morse and Herrnstein, 1956; Herrnstein and Brady, 1958). Such a schedule provides for the sampling of a number of different kinds of behavior in a single subject within a short period of time and in a confined experimental space. The maximum advantage is gained when the components include a wide variety of behavior. This is achieved by varying the form of the reinforcer, the conditions of its delivery, and the topography of the response (Herrnstein and Brady, 1958).

This report describes the behavior of chimpanzees on a multiple schedule assembled for measuring the behavioral effects of exposure to space flight conditions. With alterations in certain features and in the temporal sequence of presentation, this schedule was that on which the chimpanzee "Enos" performed on November 29, 1961, during two orbits around the earth in a Mercury capsule. On the January 31, 1961 suborbital flight of "Ham," the avoidance portion of the schedule described here was employed. Description of the behavior of these animals during flight is presented elsewhere (Rohles, Grunzke and Reynolds, 1962).

The multiple schedule consisted of four components, each separated by an S^{Δ} period. Table 1 presents the components, the characteristics and location of their correlated stimuli, the required response topography and lever location, and the form of reinforcer. It also shows the duration and sequence in which the various schedules were in effect.

Subjects

The data are based on four chimpanzees, three males (No. 35, 64, 65) and one female (No. 44), ranging in age from 1 to 3 yr. The subjects (*S*s) were deprived of food and water for 18 hr prior to each training session and were fed and watered once daily. They were maintained on an 800-cal, low-bulk diet. Water was freely available for ½ hr following each training session. Training sessions were approximately 5-½ hr long. Subjects used only on avoidance procedures were not deprived.

Apparatus

Initial training on the avoidance and DRL schedules was accomplished with the *S* seated in a chair and restrained by a neck yoke and clamps over both thighs and both ankles. The chair and associated apparatus are shown in

[1]Reprints may be obtained from R. E. Belleville, Chief, Behavioral Biology, Office of Bioscience Programs, Headquarters, National Aeronautics and Space Administration, Washington 25, D. C.

[2]This work was conducted for the National Aeronautics and Space Administration as part of Project Mercury.

Table 1

Schedule	*Stimulus (S^D) Lights*	*Location*	*Lever*	*Form of Reinforcement (rft)*	*Time in Effect*	
Sidman avoidance 10 second R-S interval	Red	Right Display	Right	Shock White light as secondary rft	10 minutes	Concurrent
Discriminated avoidance. S^D — Shock interval = 5 seconds	Blue	Left Display	Left	Shock	2 minute fixed interval presentations	Concurrent
Time Out (S^{Δ})	None (dark)	....	....	....	2 minutes	
Differential rft of low response rate (10 second)	Green	Right Display	Right	Green light on water dispenser	10 minutes	Chained
Consummatory drinking response	Green	On water dispenser	Lip lever on water dispenser	Water	Response dependent	Chained
S^{Δ}	None	....	....	....	2 minutes	
Fixed ratio 50/1	Yellow	Center Display	Center	Food	10 minutes	
Symbol discrimination; continuous reinforcement, 15 second S^{Δ} for errors	Odd of 3 symbols	Varied	Under odd symbol	Food	18 presentations; 10 minute limit	
S^{Δ}	None	....		....	2 minutes	
Repeat Cycle						

Fig. 1. Three in-line displays and three levers were mounted in a metal box directly in front of the *S* at waist level. The levers were 1 in. in diameter and protruded 2-¼ in. from the box. Excursion of the lever tip was 2 in. with a 1-in. overtravel.

Each display unit was capable of projecting a red, green, yellow, white, or blue disc of light on a dark 1 × 1¼ in. ground glass surface. The display units could also be programmed to present any of seven white symbols; a circle, triangle, and square were used in this study.

Reinforcement devices included a modified commercial feeder which delivered 1-g food pellets[3] and a liquid dispenser specifically designed for primates (Grunzke, 1961). The appropriate lever response illuminated a light mounted on the water dispenser. A lip lever and drinking tube were mounted just below the light. One cc of water was dispensed into the *S*'s mouth when the lip lever was pressed in the presence of the water light. The arrangement of feeder, hopper, and water dispenser is shown in Fig. 1.

For delivery of shock, brass foot pedals spring-hinged to the chair maintained continuous contact with the feet, yet allowed some movement. Modal shock values were 4.5 ma and 100 v, 60 cycle AC and 0.5 sec in duration.

Early training on the symbol discrimination task and on the fixed-ratio schedule was conducted with the subjects in a chamber described by Rohles (1961). The arrangement of displays and levers was the same except that they were mounted on the wall of the chamber.

PROCEDURE

1. *Avoidance*

The Sidman (1953) procedure was employed using an S-S interval of 2 sec. During training, the R-S interval was 20 sec; this was reduced to 10 sec after adding the other components

[3]We are indebted to Dr. Dom V. Finocchio, Ciba Pharmaceutical Products, Inc., for providing the pellets.

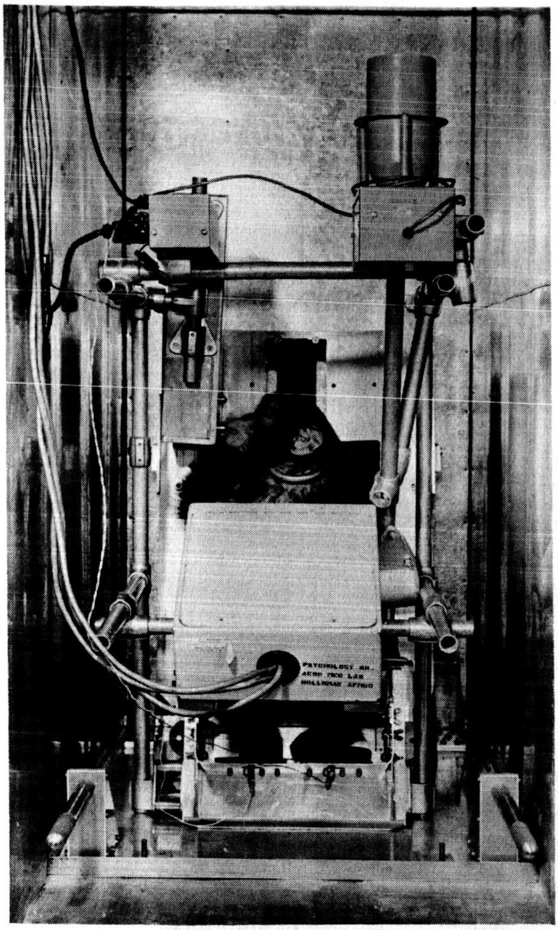

Fig. 1. Chimpanzee chair and associated apparatus with *S* operating lip lever.

of the schedule. Each lever depression was followed by a 0.3-sec flash of white light in the center display. With some animals, avoidance and extinction were alternately programmed. A red light (S^D) was correlated with the Sidman avoidance procedure, and a green light (S^Δ) signalled extinction. The green light was later used to signal DRL. After this behavior was well established, a discriminated avoidance procedure was introduced using an additional light and lever. This required the *S* to make a single response on a second (left) lever when a blue light was illuminated. Failure to make this response within 5 sec resulted in delivery of a shock and termination of the blue light. A response on the left lever turned off the blue light and prevented the occurrence of shock. The blue light was presented at variable intervals with a 2-min mean during training and at regular 2-min intervals after introducing the remaining components.

2. *Differential Reinforcement of Low Response Rate*

The DRL schedule (Wilson and Keller, 1953; Sidman, 1956) using a 10-sec delay period was programmed using the right-hand lever. A response made after the 10-sec waiting period turned on a light above the liquid feeder. When this light was on, pressure on the lip lever delivered 1 cc of water. Following an effective response, a new timing cycle did not begin until the lip lever was pressed. This procedure was preceded by training on the lip lever. The *S* was exposed to S^D periods during which the water feeder light was presented and water was available on a continuous reinforcement basis for lip lever responses. Availability was alternated with S^Δ periods during which the water light was off and no reinforcement was given.

3. *Odd Symbol Discrimination*

On this component, 18 sets of three symbols appeared consecutively on the display units. Two of the symbols were alike, while the other was different (odd). For magazine training, the *S* was placed in the chamber and presented pellets accompanied by a 5-sec presentation of a single symbol at 60-sec intervals. Following this, the symbol was presented and a lever response under the symbol resulted in food reward. Thereafter, symbols were presented on all three displays. A response under the display having the odd symbol was reinforced and the next set was presented immediately. An incorrect response was followed by a time-out period of 15 sec.

4. *Fixed Ratio*

This schedule required the *S* to respond 50 times on the center lever in the presence of a yellow light in the center display position. Reward was a 1-g pellet of food.

RESULTS AND DISCUSSION

The development of avoidance behavior in the chimpanzee "Ham" (No. 65) is shown in Fig. 2. The record presented here shows the 1st through the 17th hr of training. It is similar in all essential features to avoidance acquisition in chimpanzees described by Clark

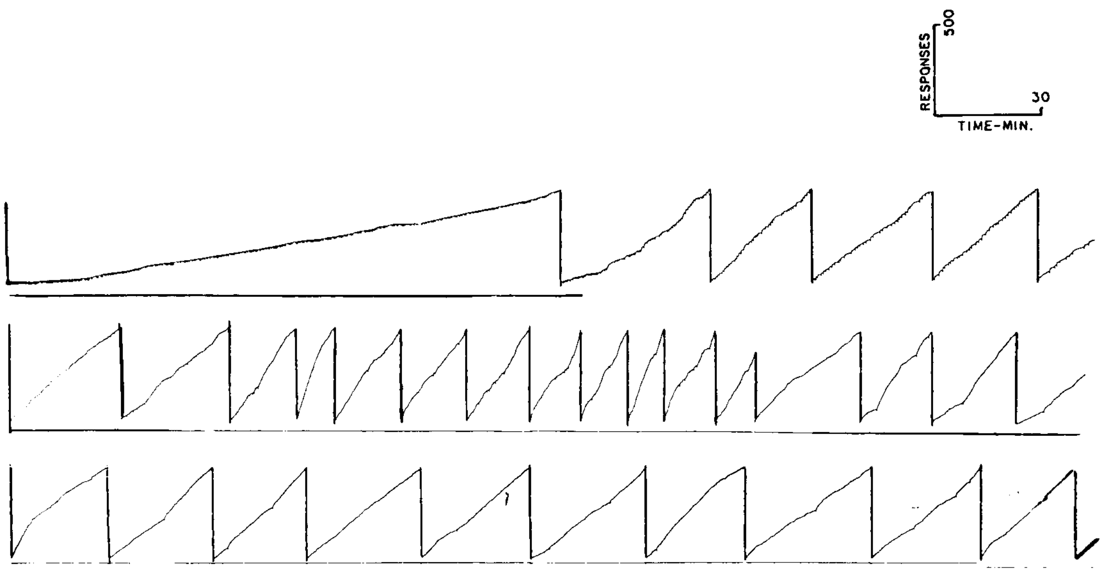

Fig. 2. Sample record showing acquisition of avoidance behavior by the chimpanzee.

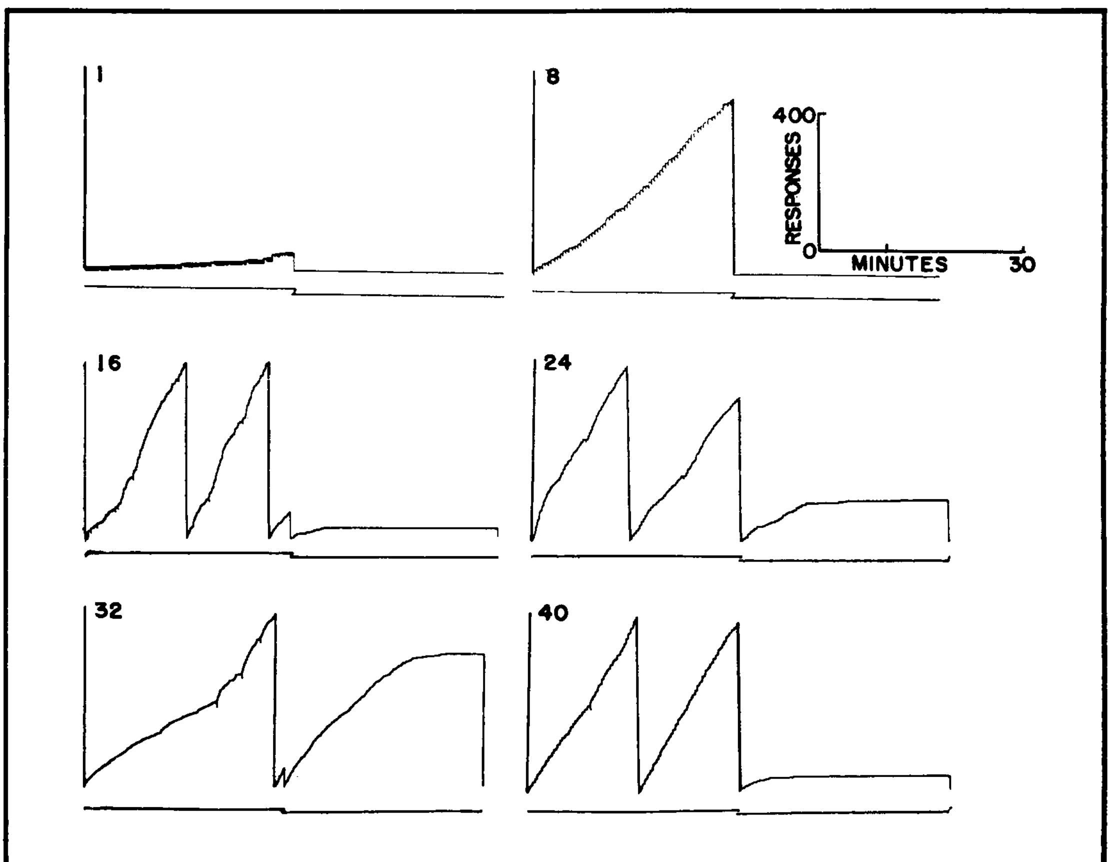

Fig. 3. Record showing concurrent development of avoidance and avoidance discrimination. Details of the procedure are given in the text.

(1961), although a continuous record of its development is presented here.

Figure 3 illustrates the simultaneous acquisition of avoidance and discrimination of the avoidance-extinction contingency during the 1st, 8th, 16th, 24th, 32nd, and 40th hr of training for *S* No. 35. Thirty minute S^D-S^Δ periods were used. The sequence of changes in rate and grain are similar to acquisition without discrimination, although the rate in S^D is higher when compressed between S^Δs. As illustrated in Fig. 3, only shocks are the occasion for responding in early avoidance acquisition. Responding in S^Δ is absent, suggesting that behavior other than avoidance had not yet become aversive. When this does occur, *i.e.*, when pauses precede burst of responding in S^D, there is a concurrent increase in responding in S^Δ. The subsequent extinction of responding in S^Δ occurs as the visual stimulus gains control. This is consistent with the account of the development of avoidance behavior in terms of the acquisition of aversive properties of the stimulus consequences of behavior other than the avoidance response (Schoenfeld, 1950).

An attempt was made to introduce the discriminated avoidance procedure by simply superimposing it upon the Sidman avoidance schedule. When the left lever was introduced and the blue light was presented, the *S* immediately began responding on both levers simultaneously. When responses on the left lever, made in the absence of the discrete avoidance signal, were punished, the rate on both levers increased with phases of simultaneous and alternate responding on left and right levers.

To prevent simultaneous responding on both levers, or adventitious reinforcement of

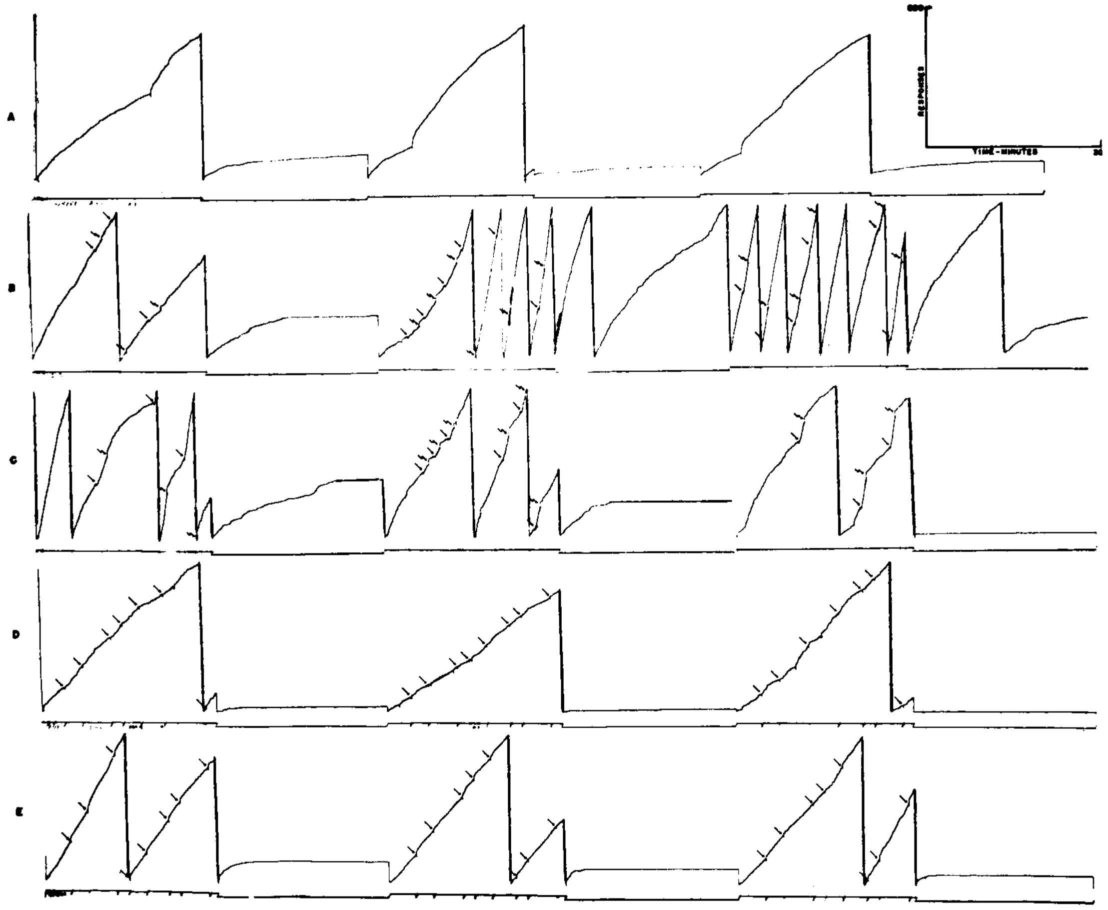

Fig. 4. Sample record showing superimposition of discriminated avoidance on Sidman avoidance baseline. Arrows indicate presentation of blue stimulus light. Corresponding marks on event line show left-lever responses. Broken arrows indicate delivery of shock.

left-right response sequences, another procedure was adopted which proved to be more successful. The left lever was removed and the blue light was presented at random intervals. After each 1-min presentation, the light was terminated and shock was delivered. Thus, the operations at this point were the same as those in the conditioned facilitation procedure of Sidman, Herrnstein, and Conrad (1957). The left lever was then introduced, providing control over both the blue light stimulus and shock.

The results of these procedures are shown in Fig. 4 which presents samples from successive records of *S* No. 44. The first record shows performance on the Sidman schedule after approximately 30 hr with alternating 30-min avoidance and extinction phases. The rate here is relatively steady, while responses in S^{Δ} are minimal. The initial effect of introduction of the blue light-shock sequence is shown in Record B. The increase in S^{Δ} responding is concomitant with an increase in the overall avoidance rate. The development of discrimination of the blue light-shock contingency is demonstrated by the increase in rate during presentation of the blue stimulus light. The development of this differential rate is correlated with the decrease in S^{Δ} responding. As the conditions under which shock is delivered are discriminated, a decrease in induction occurs between S^{D} and S^{Δ}. The increase in rate during the pre-aversive stimulus is correlated with a decrease in S^{Δ}.

Record D shows the performance 3 hr after introduction of the left lever and reduction of the light-shock interval to 5 sec. Responses on the right lever were cumulated in the usual fashion while responses on the left lever were recorded as deflections of the horizontal line. Performance after 16 hr on this schedule is shown in Record E. For the period shown here, no responses were made in the absence of the blue light. However, six extra or "double" responses were recorded after its presentation. Mean reaction time for 24 pres-

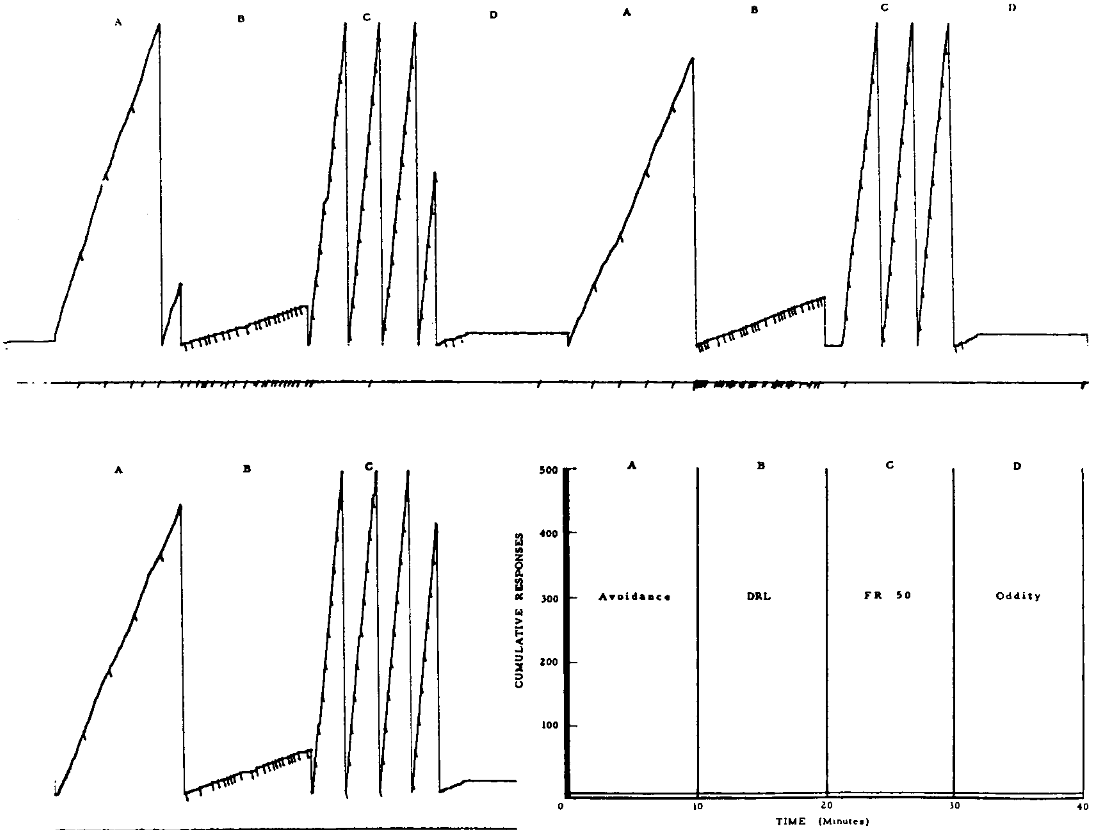

Fig. 5. Cumulative record showing three consecutive cycles of multiple schedule performance. The manner of recording data in each component of the schedule is described in the text.

entations was 0.76 sec with no failures to respond upon presentation of the blue stimulus. Some increase in the avoidance rate on the other lever occurred after each presentation of the blue light. Removal of the left lever resulted in a higher rate on the right lever, rather than suppression which might be expected if the left and right lever responses were under entirely independent control.

A record obtained from *S* No. 64 is presented in Fig. 5 which shows three consecutive cycles of performance on the multiple schedule. Responses on the correct lever were recorded in a cumulative fashion as a function of time, with the pen resetting after 500 responses and following each change in schedule. The recorder was stopped during the time-out (S^{Δ}) periods between each of the component schedules. Thus, the passage of time in S^{Δ} is not shown in Fig. 5.

For the avoidance component (A), responses on the right-hand lever were cumulated, while responses on the left lever were recorded as deflections on the horizontal line (event pen). Each presentation of the blue light is shown as a diagonal mark on the cumulative curve. Shocks were to be recorded in the same manner, but none occurred. With the DRL procedure (B), the diagonal mark on the curve indicates that the response was made after the required interresponse time and marks on the horizontal event line indicate lip lever responses. On the fixed ratio schedule (C), diagonal marks indicate reinforcements. For the odd-form discrimination (D), correct responses were cumulated, while *incorrect* responses are shown as diagonal marks. The flat portion of the curve represents time remaining in the 10-min segment after completion of the 18 oddity discriminations.

Although the two avoidance procedures were previously termed "continuous" for the Sidman schedule and "discrete" for the superimposed avoidance feature, further observations suggested that the right lever-left lever response sequence becomes chained. During early training, punishment was programmed when responses were made on the left lever when the blue light was not on. This feature was later eliminated since superfluous responding appeared to be somewhat self-limiting, particularly when a relatively short R-S interval was employed. After initial training, a shock following the blue light presentation is extremely rare, suggesting that the left-lever response is maintained partly by induction from the Sidman schedule on the right lever.

An accurate appraisal of timing behavior on the DRL schedule was not possible since a distribution of inter-response times was not obtained. The hand lever-lip lever sequence appears to eliminate bursts of responding on the hand lever although responses following very short intervals are quite frequent on the lip lever.

On the ratio component, pausing after reinforcement was observed in this animal during early training; but, with further exposure to the FR schedule, these pauses disappeared and a high rate was maintained throughout the 10-min period of exposure to the FR component. The effect of satiation is seen as a late start, *i.e.*, failure to begin responding when the schedule is in effect. The resemblance of this record to that usually obtained under variable interval reinforcement schedules may be attributable to the fact that only one hand was used in operating the lever, and that eating was accomplished with the other hand at irregular intervals and occasionally after several pellets were available. The pause after reinforcement characteristic of FR schedules is observed, however, in animals that use both hands to manipulate the lever.

Accuracy of discrimination of odd symbols after prolonged exposure reaches about 90%, a level approximating that achieved in *S*s trained only on this task. The cumulative curves are similar to continuous reinforcement on a simple operant response and the performance is highly variable and sensitive to disruption from minor distractions such as noise.

In addition to the problem of maintaining independence of behavior in a multiple schedule using a single lever, further difficulties are introduced when several levers are employed and when all levers are immediately accessible. On the fixed ratio and DRL procedures, no control was exerted over responding on levers other than the correct one. This, of course, may invite adventitious reinforcement of response sequences. Shortly after the component schedules were assembled, *S* No. 64 developed a rapid left lever-center lever sequence on the ratio schedule at a FR 20 value. Preventing the left-lever response by removing this lever and reduction of the ratio to continuous reinforcement, followed by very gradual increases in the ratio effectively eliminated this response sequence. The ratio was not increased to FR 50 until the correct lever was well differentiated.

With the DRL procedure, no such behavior was observed. In this case, the effect of incorrect lever responses appeared to produce better lever differentiation. Informal observations showed that responding on a wrong lever initiates another "waiting" period rather than a response on an alternative lever, although this was not explicitly programmed. For all schedules, discrimination of the visual stimuli progressed much more rapidly than did lever differentiation. The sharp contrast between response rates on each of the schedules, and the absence of responses in S^{Δ} and on inactive levers, illustrates the high degree of both stimulus discrimination and response differentiation finally achieved. The total absence of responses in S^{Δ} is seldom observed in animals other than the chimpanzee. There are, of course, many possibilities for interaction between component schedules, as well as the response sequences within components which will require further experimental analysis.

In assembling the multiple schedule described here, an attempt was made to include, as far as possible, different forms of behavior, motivations, response manipulanda, and different controlling and reinforcing stimuli. With the present limitation to single *S* participation in space flight experiments, an ideal multiple schedule would include an even wider range of experimental operations and their various combinations. Such a balanced experimental design within a single *S* is entirely feasible. The ease with which new behavior may be added to the repertoire of the chimpanzee suggests that its behavioral capacities in both breadth and complexity have not yet been approached.

REFERENCES

Clark, F. C. Avoidance conditioning in the chimpanzee. *J. exp. Anal. Behav.*, 1961, **4**, 393-395.

Ferster, C. B. and Skinner, B. F. *Schedules of reinforcement.* New York: Appleton-Century-Crofts, 1957.

Grunzke, M. E. A liquid dispenser for primates. *J. exp. Anal. Behav.*, 1961, **4**, 326.

Herrnstein, R. J. and Brady, J. V. Interaction among components of a multiple schedule. *J. exp. Anal. Behav.*, 1958, **1**, 293-300.

Morse, W. H. and Herrnstein, R. J. Effects of drugs on characteristics of behavior maintained by complex schedules of intermittent reinforcement. *Ann. N. Y. Acad. Sci.*, 1956, **65**, 303-317.

Rohles, F. H. The development of an instrumental skill sequence in the chimpanzee. *J. exp. Anal. Behav.*, 1961, **4**, 323-325.

Rohles, F. H., Grunzke, M. E., and Reynolds, H. H. Chimpanzee performance during the ballistic and orbital Project Mercury flights. Henry, J. P. and Mosely, J. D. (Eds.) Results of the Project Mercury ballistic and orbital chimpanzee flights. NASA SP-39. Available from Superintendent of Documents, U. S. Govt. Printing Office, Washington, D.C.

Schoenfeld, W. N. An experimental approach to anxiety, escape, and avoidance behavior. *Anxiety.* Hoch, P. H. and Zubin, J. (eds.) New York: Grune and Stratton, 1950.

Sidman, M. Avoidance conditioning with brief shocks and no exteroceptive warning signal. *Science*, 1953, **118**, 157-158.

Sidman, M. Time discrimination and behavioral interaction in a free operant situation. *J. comp. physiol. Psychol.*, 1956, **49**, 469-473.

Sidman, M., Herrnstein, R. J., and Conrad, D. G. Maintenance of avoidance behavior by unavoidable shocks. *J. comp. physiol. Psychol.*, 1957, **50**, 553-557.

Wilson, M. P. and Keller, F. S. On the selective reinforcement of spaced responses. *J. comp. physiol. Psychol.*, 1953, **46**, 190-193.

Received October 26, 1962